Cognitive Health

Can Video Games Improve Your Brain?

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What is Cognitive Impairment?

With the growing prevalence of cognitive decline, there is a need for sustainable lifestyle interventions to support, maintain, and improve cognitive health. As physical exercise bolsters bodily health, so too is there a need for mental training. The evolution of technology offers new, promising mediums for cognitive training. This medium is the realm of virtual reality, video games, and mobile devices, that allow for the development of individualized training regimes tailored to suit the person's needs. There may also be potential for a virtual intelligence that may be able to preserve that which the brain can no longer contain. This review explores the research behind the application of video games to cognitive exercise, rehabilitation programs encompassing virtual realities, and smart phones dedicated to maintaining access to faculties challenged by the progression of Alzheimer's disease ("virtual intelligence").

Alzheimer's disease is estimated to affect 1% of persons 60–70 years of age, and 6–8% of those over 85.[1] On the other hand, mild cognitive impairment (MCI) is a milder form of cognitive loss, affecting an estimated 10–20% of those 65 and older.[2] These numbers are only expected to grow with the aging population. There is a growing need for lifestyle interventions that are accessible, effective, economically sustainable, and that elicit good compliance. Some of the early signs of cognitive decline can include mild memory loss, as well as mild reduction in reasoning, processing speed, and executive function, such as attention, language, and visuospatial skills.[2, 3] Executive function means a set of mental processes that helps connect past experience with present action in order to perform activities such as planning, organizing, strategizing, paying attention to and remembering details, and managing time and space.

The prevalence of mild cognitive decline, as well as Alzheimer's disease (AD) and dementia, is expected to increase as baby boomers age.[4] Currently the causes of

cognitive decline range from normal aging (age-associated cognitive decline), mild cognitive impairment (slightly more significant cognitive decline compared to normal aging), as well as more serious causes such as Alzheimer's disease, hypothyroidism, vitamin B_{12} deficiency, cerebrovascular disease (i.e. vascular dementia), adverse effects of medications (especially a problem in the elderly), cancer, infections of the central nervous system, substance abuse, HIV-related cognitive disorder, and others.[1] A reduction in verbal memory and executive function, coupled with reduced retention of newly acquired information are more indicative of Alzheimer's disease, while memory loss associated with psychosis is more characteristic of dementias.[1] In this context, psychosis refers to a mental loss with external reality, impairing emotions and thought processes.

As computers and mobile devices become more commonplace, their application to cognitive health offers a promising intervention that is relatively inexpensive and customizable, and is able to address the individual needs of patients. There is preliminary evidence suggesting that regular use of such technology may help maintain brain health. Evidence from a recent prospective study correlates the use of daily computers with 30–40% lower risk of dementia.[5] A total of 5506 healthy men between 69 and 87 years of age were followed forward for six years, with the primary outcome of interest being the diagnosis with dementia. Computer use was defined as activities such as browsing the Internet, e-mail, word processing, and playing games. Though there may be a range in the degree of benefit from computer use, potentially dependent on the quality of content viewed, one simple factor that does seem to have a potentially beneficial effect is experience. Another study by Small et al. compared the functional MRI recordings of experienced users with those not familiar with the Internet.[6] Functional MRI shows specific areas of the brain lighting up depending on what brain functions are engaged. This study found that regular Internet use correlated with activation of brain areas associated with decision making and complex reasoning, while inexperienced Internet browsing resulted in activation of areas associated with reading only. Thus, there is some evidence to support the use of computers in the elderly population as a means to promote cognitive health. We will now take a closer look at a few specific computer-based interventions and their impact on cognitive function.

Video Games

A 2012 systematic review provides an excellent overview of the landscape of video games and their current therapeutic potential.[7] The review included eight studies conducted in participants aged 50–87, and the impact of video games on cognition was examined. Some of the games included were Nintendo Wii's Big Brain Academy, Rise of Nations, Medal of Honor, Pac Man, Donkey Kong, Tetris, Atari: Break out, Crystal Castles, Galazian, Frogger, and Kaboom. These were played for two to five hours each week over a period of two to 11 weeks. The largest improvements were seen for reaction time (effect size of 0.77; in this case the closer the effect size is to 1.0 the stronger the effect), processing speed (0.72), and global cognition (0.69). Global cognition was evaluated using two questionnaires called the WAIS-R full IQ and ADAS-Cognition. A milder impact was made on executive function (0.25) and attention (0.21). The degree of impact varied across the different games examined. Except for Brain Academy, none of the above-mentioned games focus on improving cognitive function.

Contradictory to popular belief, games stereotypically seen as "intellectual" do not necessarily yield cognitive improvements, as demonstrated in a study by Boot et al.[8] Healthy participants of average age 74 years were randomized to play 60 hours of one of two games: 1) Brain Age 2 (intellectual game) or 2) Mario Kart (action game). The participants were assessed using a battery of cognitive tests including flanker test (selective attention), meaningful memory, Raven's matrices (reasoning), visual search (processing speed), and others. However, no significant changes were reported after 12 weeks for either game.

To determine which game type may provide the most cognitive benefit, a study by Oei et al. compared several different types of games in a group of undergraduate university students.[9] Seventy-five students were randomly assigned to one of the five games: Memory Matrix (reproduce a sequence), The Sims (life simulation), action (first-person shooter), match-3 (Bejewelled 2), or hidden-object (find object within a complex visual scene). They were instructed to play for one hour per day, five days per week, for a total of four weeks (20 hours in total). Before and after the game intervention, the students were assessed using a wide array of cognitive tests. The tests included attentional blink, filter task, visual search/spatial memory, and complex span. The results of the study showed that the action game resulted in significant improvement in attentional blink ($p < 0.001$). The researchers speculated that this might be due to the need to rapidly switch attention between targets, specific to the nature of action games, which results

in improved attention-switching transferable to tasks outside the game. The action game also resulted in improvements in the filter task, the ability to track multiple objects simultaneously, and complex span, a combination of arithmetic and verbal memory tasks. On the other hand, Bejewelled 2 yielded positive results on visual search/spatial memory and complex span. Memory matrix and hidden-object were beneficial for visual search/spatial memory only, while The Sims did not make a significant impact on any of the four parameters. Thus it would seem that the action game offers the most broad spectrum of benefit, though some cognitive benefit can be elicited from the other games as well.

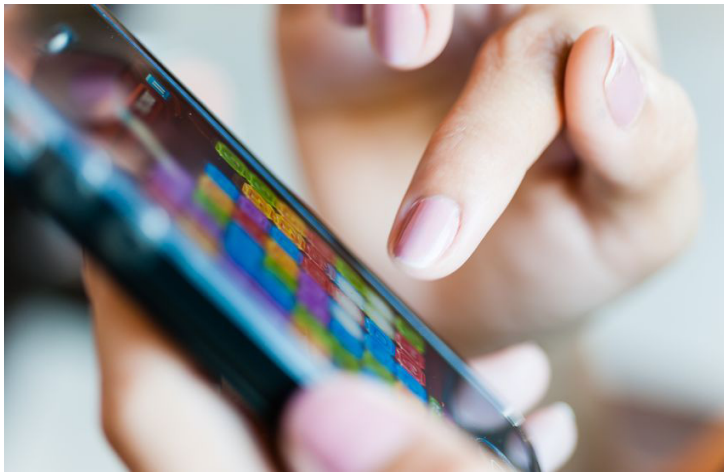
Virtual Training

Though potentially less entertaining than video games, virtual-reality (VR) training programs, designed to improve specific skills, are already delivering effective interventions to both healthy elderly participants and those suffering with Alzheimer's disease.

A study by Optale et al. demonstrated therapeutic effects from VR training on several cognitive parameters in the healthy elderly population.[10] This randomized control trial enrolled 36 participants with an average age of 80 years, who had various degrees of impairment on the Verbal Story Recall (VSR) test. These participants were divided into either the experimental group, or the control group, which received music therapy. The experimental group received three training sessions every two weeks, consisting of both auditory and VR training. The auditory training consisted of listening to an audio recording of three different stories with three different musical backgrounds, while VR training consisted of finding the correct path to a viewing location of a 15-second film clip, using a joystick and computer while listening to the same background music as used in the audio training. The training was delivered for three months. At the end of the study, the training resulted in significant improvements in the Mini Mental State Examination (MMSE) ($p = 0.014$), Digit Span test (short-term verbal memory; $p = 0.043$), Verbal Story Recall (VSR) ($p < 0.001$), Phoenemic Verbal Fluency ($p = 0.005$), and Geriatric Depression Scale ($p = 0.025$), while the control group either maintained or demonstrated loss of function. No changes were observed in visuospatial processing and activities of daily living.

Using VR as a safe and controlled training environment, Hofmann et al. created a shopping intervention to improve daily living function of patients with AD.[11] The VR

experience was created using digital photographs of the shopping route, which the participants were required to navigate in order to locate the shop, buy three items, and answer 10 relevant multiple-choice questions, such as “You will have to cross this road to get to the pharmacist. What do you have to keep in mind?” After 12 sessions over four weeks, a significant reduction in the number of mistakes made ($p < 0.044$) was documented, which was sustained for three weeks following the training. No impact on the MMSE was observed. While the study demonstrated ability to improve specific skills, it is difficult to conclude how generalizable these gains are to the real-life shopping experience. It is also unclear how long past the three-week follow-up the benefits may persist.



Other Ways of Applying New Technologies

As the world of games and virtual realities continues to evolve, so does the world of its applications. Amazingly, a case study by De Leo et al. capitalized on the photographic capacity of the smartphone in order to develop what could be called a virtual memory for a patient with Alzheimer’s disease.[12] The participant was diagnosed with stage 4 Alzheimer’s disease and was given a programmed smartphone, which he wore around his neck for four weeks. The phone was programmed to capture pictures every five minutes between 8:00 a.m. and 8:00 p.m. The images were uploaded automatically to a server at 2:00 a.m. each night. Redundant or poor-quality images were discarded by the research team, and the rest were made into a slideshow, which the participant viewed once a week. A recent-events memory-recall test was administered before and immediately after viewing the video, along with a five-point Likert-scale satisfaction questionnaire. Not surprisingly, viewing of the slideshow increased the number of events remembered. Though the participant did not agree that the slideshow was a very useful tool as memory aid, he did agree that it made him feel less anxious knowing that it was keeping a record, especially in social situations where he was concerned about forgetting who he had met. Being able to share the experiences with family through the slideshow was an added enjoyment. The device did not pose an inconvenience to the participant, but did present with some technological problems and dependency on a video editor to sort through the slideshow.

This innovation does not end with a single case report. Another approach to creating a virtual memory is currently in the process of being piloted. Another team has developed a cell phone–based video streaming system to provide routinely scheduled reminders

to patients with dementia as a way to assist with daily activities.[13] By using the familiar faces of relatives, the developers hope to achieve higher compliance. Another potential application of the smart phone is the use of the GPS component as way of locating patients with Alzheimer's disease that become lost.[11] Finally, the application of the Wii is another area that can be explored, as well as the social benefit and cognitive impact of the virtual online communities, such as Facebook and Skype.

Challenges and Limitations

Amidst all this innovation, two main obstacles were identified in the literature with respect to these new technologies. The first and most familiar is the challenge of compliance. No therapy can help an individual who does not adhere to it. Boot et al. explored participant preferences in a study comparing two different Nintendo DS game interventions.[8] In this study, participants (mean age 74 y.o.) were randomized to play 60 hours of either an action game, Mario Kart DS, or a more intellectual game, Brain Age 2, which included the choice of several different games including sudoku. Ironically, participants rated the intellectual game more enjoyable and were more compliant with the prescription (56 hours on average were played of Brain Age 2 compared to 22 hours of the Mario Kart). They described Mario Kart as "mindless" and "utterly boring". Paradoxically, however, according to the research,[8, 9] it is the action games that offer the most benefit with respect to executive function and reaction speeds. The second concern is the adverse events associated with the ergonomics of computers. Some of the reported side effects of desktop monitors, joysticks, and keyboard use included eye strain and arthritis,[8] while use of head-mounted visual displays, typically used to create virtual realities, resulted in nausea, vomiting, dizziness, headaches, disorientation, and transient vestibular and psychomotor disturbances.[14] Another potential complication familiar to all of us is the frustration of technological limitations in the forms of hardware and software malfunctions. Despite these challenges, a systematic review by Kueider et al. reports that participants do not need to be technologically savvy in order to enjoy all the benefits that these intervention have to offer with respect to cognitive health.[7]

Conclusion

As the technological world continues to evolve, it may offer new tools and approaches that may aid in the maintenance of cognitive health and in the rehabilitation of various cognitive impairments. Individual needs and preferences will become crucial in the development of efficacious video games and virtual realities, which will not only need to stimulate the cognitive functioning but maintain interest and intrigue the participant, ideally while connecting them to a strong and supportive social network.

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